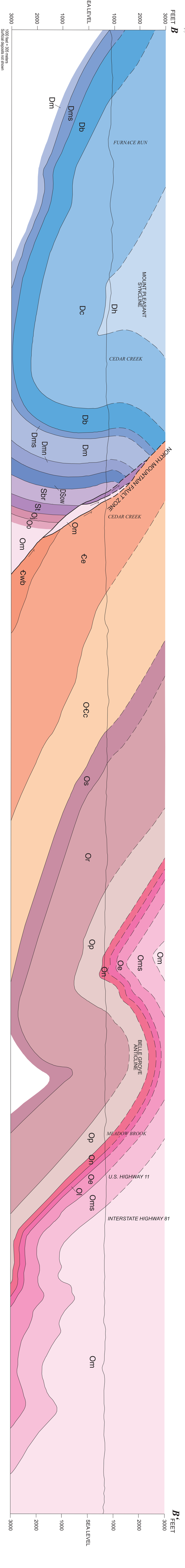
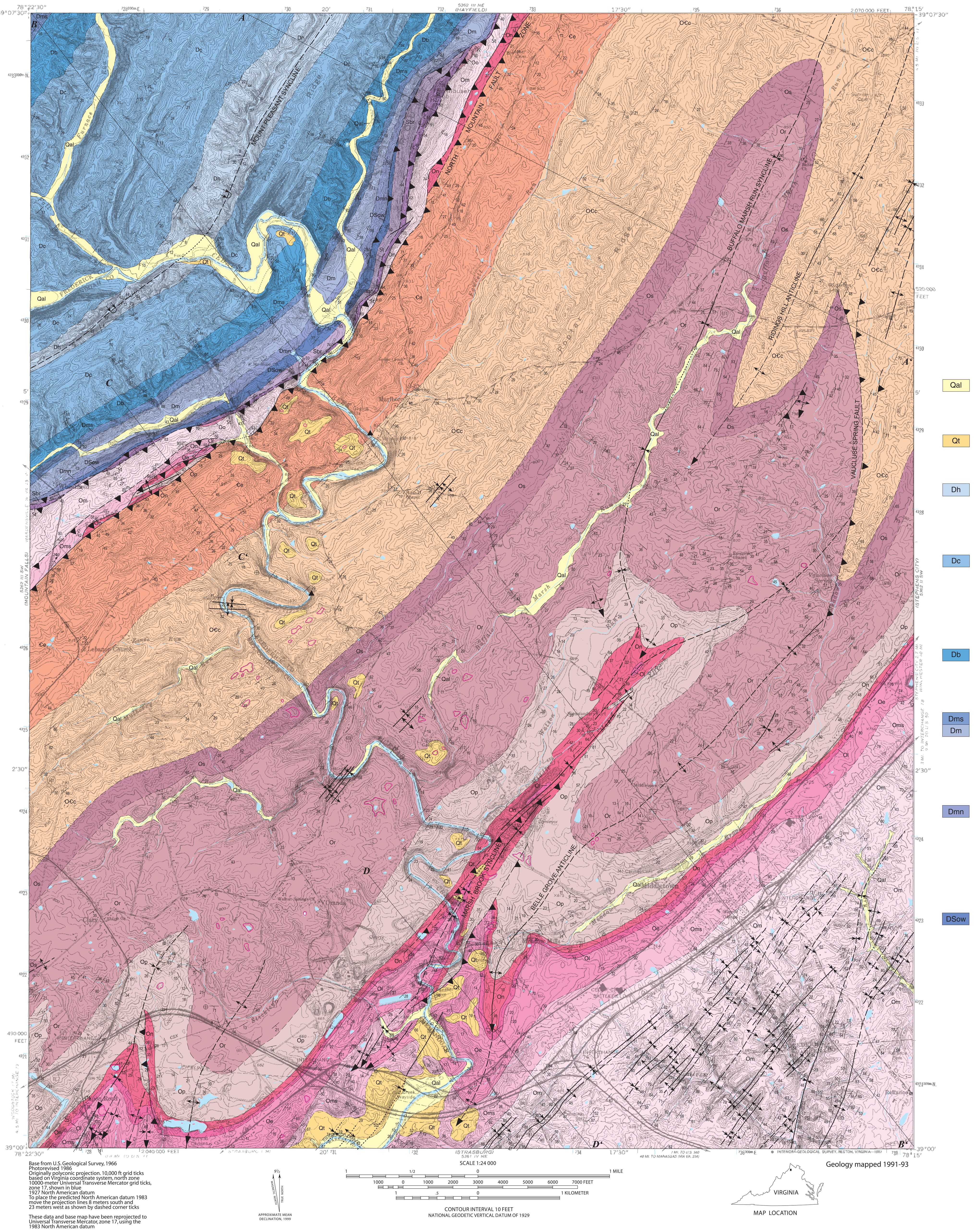




Base from U.S. Geological Survey, 1966
Photorevised 1986
Originally polyconic projection. 10,000 ft grid ticks based on Virginia coordinate system, north zone
10000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue
1927 North American datum
To place the predicted North American datum 1983 move the projection lines 8 meters south and 23 meters west as shown by dashed corner ticks

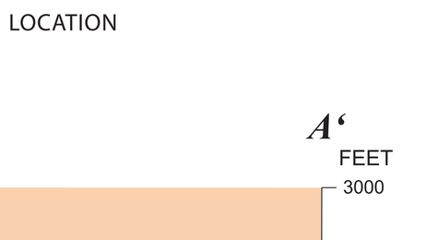
These data and base map have been reprojected to Universal Transverse Mercator, zone 17, using the 1983 North American datum

APPROXIMATE MEAN DECLINATION, 1999

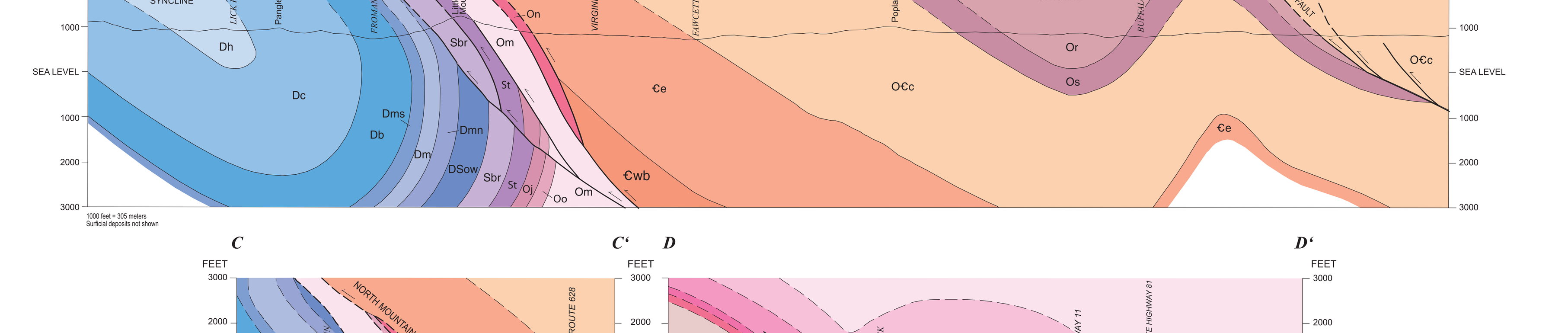
SCALE 1:24 000

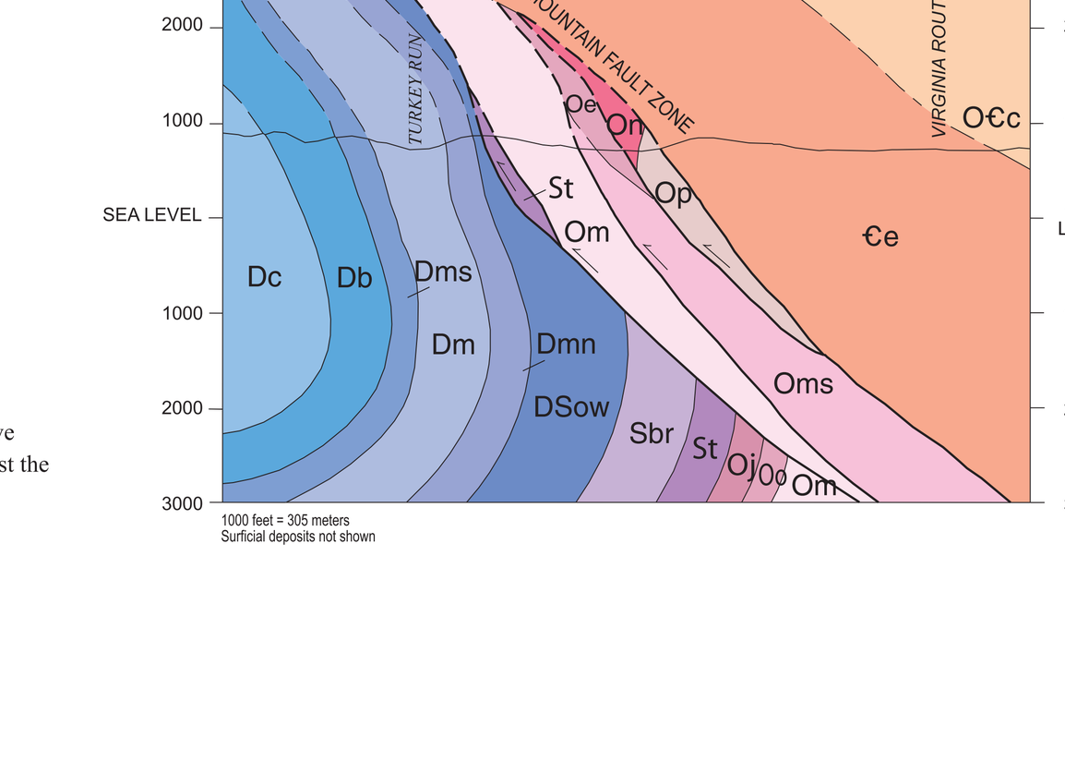
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

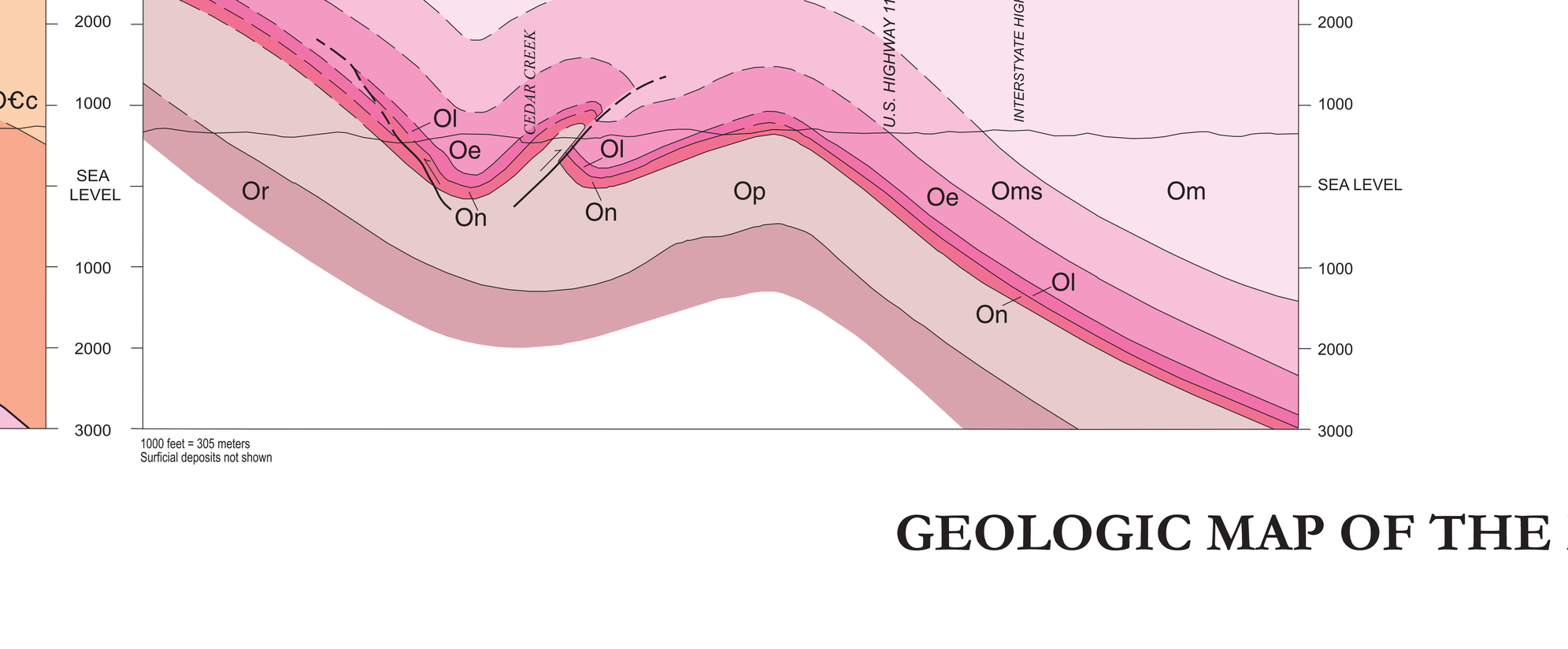
Geology mapped 1991-93



MAP LOCATION







Disclaimer: This graphic is a Geographic Information Systems (GIS) –based, digital reproduction of the original printed paper map. Although every effort was made to faithfully reproduce the original publication, errors may have been introduced during the reproduction process. Any critical, site-specific investigations should be checked against the original map. Geologic symbols used on this graphic may not be to exact USGS specifications.

CORRELATION OF MAP UNITS

Unit	Series	System
Qal	Holocene	QUATERNARY
Qt	Pleistocene (?)	QUATERNARY
Unconformity		
Dh, Dc	Upper Devonian	DEVONIAN
Db, Dms, Dm, Dmn	Middle Devonian	DEVONIAN
DSow	Lower Devonian / Upper Silurian	DEVONIAN / SILURIAN
Sbr	Middle Silurian	SILURIAN
St	Lower Silurian	SILURIAN
Oj, Oo, Om	Upper Ordovician	ORDOVICIAN
Oms, Oe, Ol, On, Op	Middle Ordovician	ORDOVICIAN
Or, Os	Lower Ordovician	ORDOVICIAN
O€c	Upper Cambrian	CAMBRIAN
€e	Middle Cambrian	CAMBRIAN
€wb	Lower Cambrian	CAMBRIAN

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene and Pleistocene?)**--Clay, silt, and lesser sand with angular to subrounded clasts, up to boulder size, derived from local bedrock. In area underlain by the Martinsburg Formation, consists of light-olive-gray, yellowish-gray, and pale-yellowish-orange to dark-yellowish-orange, well-bedded to crudely bedded, planar-bedded, clayey silt, with weathered shale fragments as much as an inch long; as much as 20 ft thick along Cedar Creek

Qt **Terrace deposits (Pleistocene?)**--Deeply weathered, grayish-orange silt matrix containing leached, generally rounded cobbles as much as 8 in. in diameter of reddish-brown and white sandstone, probably derived from rocks of Silurian and Devonian age. Thickness locally as much as 50 ft or more along Cedar Creek. Two terrace levels occur at about 40 and 80 ft above Cedar Creek

Dh **Hampshire Formation (Upper Devonian)**--Shale, mudstone, siltstone, and minor sandstone, grayish-red to brownish-gray, medium- to thick bedded, in part micaceous and (or) arkosic; unfossiliferous. Thickness as much as 750 ft. Upper part of formation not present in quadrangle. Lower contact placed at base of redbeds and at top of highest gray, fossiliferous sandstones and shales of underlying Chemung Formation. Exposed in core of the Mount Pleasant syncline in northwestern corner of quadrangle; best exposed on steep slopes northeast of the Virginia Highway 606 ford of Cedar Creek and along Lick Run

Dc **Chemung Formation (Upper Devonian)**--Interbedded sandstone, siltstone,and minor shale. Sandstone, brownish-gray, medium- to coarse-grained, medium- to thick-bedded, in part crossbedded; some beds conglomeratic, most abundant in upper part of unit; many beds very fossiliferous. Siltstone, medium to thick bedded, dominant in lower part of unit. Shale, thinly interbedded with sandstone and siltstone throughout section. Interbedded brownish-red sandstones and shales, in beds or sets 3 to 40 ft thick, occur mainly in upper part of unit. Thickness about 2,500 ft. Base gradational; contact placed at base of medium- to thick-bedded, fossiliferous sandstones. Exposed along flanks of Mount Pleasant syncline in northwestern corner of quadrangle; well exposed along Cedar Creek and in Huffman Hollow

Db **Brallier Formation (Upper Devonian)**--Interbedded shale, siltstone, and sandstone, dark-gray to greenish-gray, weathers light-brownish-gray; grain size increases irregularly upward in section, sandstones more abundant in upper part; thin to medium bedded; sparsely fossiliferous. Thickness ranges from 700 to 1,500 ft. Base placed at top of thick sandstone sequence marking top of Mahantango Formation. Exposed along flanks of Mount Pleasant syncline in northwestern part of quadrangle; best exposed along Cedar Creek and upper reaches of Froman Run

Dms, Dm **Mahantango Formation (Middle Devonian)**--Mudstone, sandstone, and shale. Mudstone, dark-gray to olive-gray, hackly weathering, locally very fossiliferous; bedding obscure; spheroidal weathering common. Sandstone (Dms), medium-gray, fine-grained, medium- to thick-bedded, generally massive, locally fossiliferous; occurs as two units at top of formation, separated by mudstone; upper unit 40 to 60 ft thick, lower unit 20 to 40 ft thick. Total thickness of formation ranges from 950 to 1,050 ft. Lower contact gradational; placed at base of olive-gray beds above underlying Marcellus Shale (Dmn). Exposed on northwest flank of Little North Mountain and in extreme northwestern corner of quadrangle; best exposed in roadcuts along Virginia Highway 623 between Wheatfield and Cedar Creek

Dmn **Marcellus Shale and Needmore Shale, undivided (Middle and Lower Devonian)**--Shale and mudstone. 70 to 500 ft thick

Marcellus Shale (Middle Devonian)--Shale, dark-gray to black, highly fissile, with beds of dark-gray, argillaceous limestone or calcareous shale. Thickness 50 to 500 ft. Grades downward into Needmore Shale. Best exposed in Cedar Creek and in Froman Run just south of Virginia Highway 623

Needmore Shale (Middle and Lower Devonian)--Shale and mudstone, dark-greenish-gray to olive-gray, fossiliferous. Thickness about 20 ft. Base placed at top of sandstone or limestone of underlying Oriskany Sandstone or Helderberg Group (DSow) locally absent due to faulting. Exposed along northwest flank of Little North Mountain; well exposed along Cedar Creek

DSow **Oriskany Sandstone through Wills Creek Formation, undivided (Lower Devonian and Upper Silurian)**--Sandstone, limestone, and shale. Thickness as much as 545 ft. Individual units locally thinned or absent due to faulting

Oriskany Sandstone (Lower Devonian)--Sandstone, light-gray, yellowish-gray- or yellowish-brown-weathering, medium- to coarse-grained, medium- to thick-bedded, locally crossbedded, calcareous; locally conglomeratic with quartz pebbles up to 0.5 in. long; friable when weathered; contains molds of brachiopod shells. Base placed at top of cherty limestone of the Licking Creek Limestone of Helderberg Group. Thickness as much as15 ft; thinned or locally absent due to faulting. Exposed along Virginia Highway 55 at Wheatfield where it is 4 ft thick, along Cedar Creek where it is 2 ft thick, and at gap of Turkey Run where it is 15 ft thick

Helderberg Group, undivided (Lower Devonian and Upper Silurian)--Includes Licking Creek, New Creek, and Keyser Limestones. Limestone, medium- to dark-gray, fine-grained, irregularly bedded, fossiliferous; contains black chert nodules, lenses, and beds as much as 1.5 ft thick near top; some limestone is medium gray, coarse grained, crinoidal. Thickness about 150 ft. Lower contact placed at base of crinoidal limestone overlying platy, laminated limestone of the Tonoloway Limestone. Poorly exposed, thinned or locally absent due to faulting. Best exposed in and near a small quarry in gap of Turkey Run, along Cedar Creek, and on west slopes of Little North Mountain north of Baldwin Gap

Tonoloway Limestone (Upper Silurian)--Shale and limestone. Limestone, medium-gray to medium-dark-gray, crinkly laminated to thin-bedded. Shale, medium-gray to dark-gray, calcareous. Locally contains ripple marks and mud cracks. Base placed at predominantly laminated, relatively clean limestone above silty, sandy, or shaly limestone of the Wills Creek Formation. Unit poorly exposed. Partially exposed at Baldwin Gap where it is about 170 ft thick; top of unit covered. Thickness as much as 200 ft. Best exposed at west end of Baldwin Gap, on west slopes of Little North Mountain north of Baldwin Gap, along Cedar Creek, and in gap of Turkey Run

Wills Creek Formation (Upper Silurian)--Shale, sandstone, and limestone. Basal shale, medium-gray, slightly calcareous, laminated. Sandstone, olive-gray, very fine to medium-grained, thin-bedded to laminated. Limestone, medium-dark-gray to olive-gray, very fine grained with intraclastic (edgewise) conglomerate. Shale, medium-dark-gray and greenish-gray to light-olive-gray, yellowish- to reddish-gray-weathering, crinkly laminated, calcareous. Sandstone near top of unit, massive weathering, crossbedded, 15 to 20 ft thick, probably Tavenner sandstone member of Butts and Edmundson (1966). Thickness 140 to 180 ft. Exposed on northwest flank of Little North Mountain; best exposed in Baldwin Gap and gap of Turkey Run

Sbr **Bloomsburg Formation through Rose Hill Formation, undivided (Upper and Middle Silurian)**--Sandstone, siltstone, and shale. Thickness as much as 275 ft. Individual units locally absent due to faulting

Bloomsburg Formation (Upper Silurian)--Interbedded sandstone, siltstone, and shale. Siltstone, grayish-red, reddish-brown, grayish-purple, medium-gray, light-olive-gray, and greenish-gray, thin- to medium-bedded. Sandstone, reddish-brown to grayish-red and gray, fine- to medium-grained, thin- to thick-bedded. Shale, gray, greenish-gray, and reddish-brown. Lower contact is base of red sandstone beds. Exposed in gaps and on northwest slopes of Little North Mountain. Highly faulted, only partially present or locally absent; about 110 ft thick at Baldwin Gap

McKenzie Formation (Upper and Middle Silurian)--Shale, olive-gray and light-olive-gray, fissile, and fossiliferous, siliceous siltstone. Does not crop out in quadrangle, but probably present in subsurface northwest of Little North Mountain

Keefer Sandstone (Middle Silurian)--Quartzite, medium-light-gray, coarse-grained to pebbly, massive, vitreous at base, grading up to medium-gray, medium-grained, and olive-gray, fine-grained. Does not crop out in quadrangle, but probably present in subsurface northwest of Little North Mountain

Rose Hill Formation (Middle Silurian)--Sandstone and shale. Sandstone, reddish-brown, grayish-red, grayish-purple, and gray, medium- to coarse-grained, medium- to thick-bedded. Shale, gray, greenish-gray, and reddish-brown, locally silty, hackly-weathering. Lower contact placed at base of red sandstone overlying massive quartzite ledges of Tuscarora Quartzite (St). Thickness about 75 ft. Exposed in gaps and on northwest slopes of Little North Mountain. Highly fractured in North Mountain fault zone where it is thinned and locally absent

St **Tuscarora Quartzite (Lower Silurian)**--Quartzite, light- to medium-gray, medium- to coarse-grained, thick-bedded, some beds conglomeratic. Base placed at base of quartzite ledges along North Mountain fault zone. Parts or all of formation locally removed by faulting. Thickness about 400 ft. Exposed in gaps and along crest of Little North Mountain

Oj **Juniata Formation (Upper Ordovician)**--Sandstone and shale. Sandstone, grayish-red to brown, fine- to coarse-grained, thin- to medium-bedded, locally thick bedded, crossbedded. Shale or mudrock, grayish-red; occurs as thin beds and partings, mostly near top of formation. Does not crop out in quadrangle due to faulting along North Mountain fault zone. In adjacent Mountain Falls quadrangle to the southwest, thickness is about 200 ft. Shown in cross section only

Oo **Oswego Sandstone (Upper Ordovician)**--Sandstone and conglomerate. Sandstone, greenish-gray, coarse-grained, thick-bedded, conglomeratic. Conglomerate, interbedded with sandstone, composed of rounded clasts of chert and sandstone as much as 4 in. long in a sandstone matrix. Occurs as small slivers in North Mountain fault zone; best exposed on northeast end of Funkhouser Knob, where thickness is about 20 ft thick

Om **Martinsburg Formation (Upper and Middle Ordovician)**--Interbedded shale and lesser graywacke-siltstone and graywacke-sandstone. Shale, medium-gray to dark gray and light-olive-gray, grayish-orange- and dark-yellowish-orange-weathering, commonly silty, generally noncalcareous, although calcareous intervals occur in lower part of formation. Sandstone and siltstone (immature, generally lithic graywacke), medium-gray, grayish-orange-weathering, very fine to fine-grained, commonly graded (fining upwards), lenticular, slightly calcareous to noncalcareous. Many small-scale crossbeds. Graywacke is more abundant and more thickly bedded higher in section (approximately 2,000 ft above base of Martinsburg) where it forms conspicuous ribs in creek beds and may comprise as much as 30 percent of some intervals that are several hundred feet thick. Thicker beds are generally graded and display characteristics of complete Bouma cycles, although Bouma cycles c-e appear to be most abundant. Contains a few load casts. Thickness approximately 2,600 ft; total regional thickness may be more than 5,000 ft. Best exposed in Catlett Run northwest of Virginia Highway 842; top of unit probably not exposed in quadrangle

Oms Stickley Run Member (Middle Ordovician)--Includes all rocks above highest knobby-weathering limestone of the Edinburg Formation (Oe) up to and including all rocks containing platy limestones interbedded with shales just below shales of middle part of Martinsburg Formation (Om). Limestone, medium-gray to grayish-black, olive-gray-, grayish-orange, and dark-yellowish-orange-weathering, very fine grained, laminated and very thin bedded to thin-bedded, argillaceous, commonly micro-graded. Shale, medium-gray to medium-dark-gray, and calcareous. Also includes several thin beds of yellowish-brown metabentonite. Contact with the remainder of Martinsburg is transitional where limestones become less abundant upwards. A few thin beds of graywacke, siltstone and very fine grained sandstone, generally less than 2 in. thick, are found near top. Calcareous shale averages 49 percent carbonate (range is 45 to 53 percent) and limestones average 75 percent (range is 65 to 85 percent). Includes rocks previously called Oranda Formation and several hundred feet of rock previously included within lower part of the Martinsburg Formation (Epstein and others, 1995). Thickness may be as much as 900 ft. Best exposed at its type locality along southeast side of northbound U.S. Highway 11 just past bridge over Cedar Creek

Oe **Edinburg Formation (Middle Ordovician)**--Interbedded limestone and calcareous shale. Limestone, medium- to medium-dark-gray, fine- to medium-grained, thin- to thick-bedded, irregularly bedded, knobby weathering. Calcareous shale, medium-dark- to very dark gray. Characterized by knobby weathering of fine-grained limestone beds interbedded with shale. Contains several thin beds of yellowish-brown metabentonite. Lower contact transitional with Lincolnshire Limestone (Ol) and placed at base of first knobby-weathering, argillaceous limestone; very dark gray, shaly limestone; or calcareous shale. Thickness about 500 ft. Best exposed along entrance ramp to southbound Interstate Highway 81 from U.S. Highway 11

Ol **Lincolnshire Limestone (Middle Ordovician)**--Limestone, dark-gray to very dark gray, medium- to coarse-grained, medium-bedded with bedded black chert nodules; and bioclastic limestone, medium-gray, coarse-grained, thin-bedded. Lower contact placed at base of first dark-gray, medium-grained limestone above dove-gray, micritic limestone of New Market Limestone (On). Thickness ranges from 75 to 105 ft. Best exposed along entrance ramp to southbound Interstate Highway 81 from U.S. Highway 11

On **New Market Limestone (Middle Ordovician)**--Limestone, medium-gray and dove-gray, light-gray-weathering, thick-bedded, micritic, fenestral. Lower 10 ft is medium- to light-gray, thin-bedded, dolomitic limestone interbedded with light-gray dololaminite. Base placed at top of last medium-gray, thick-bedded dolostone of Pinesburg Station Dolomite (Op) and below dolomitic limestone of the New Market Limestone. Thickness ranges from 144 to 203 ft. Best exposed along entrance ramp to southbound Interstate Highway 81 from U.S. Highway 11 and in pastures at Nieswanders Fort southwest of Virginia Highway 627

Op **Pinesburg Station Dolomite of the Beekmantown Group (Middle Ordovician)**--Dolostone and dololaminite, medium- to light-gray, buff to light weathering, fine-grained, medium- to thick-bedded with minor white and light-gray chert nodules. Weathered surfaces exhibit "butcher-block" (cross-hatched joints) structure. Also contains a few thin, medium-gray, fine-grained limestone beds in lower part. Paleokarst features of irregular bedding and collapse breccia common near top of formation. Lower contact placed at base of first light-gray, thick-bedded dolostone overlying dominantly limestone cycles of the Rockdale Run Formation (Or). Thickness ranges from 670 to 875 ft. Best exposed in pastures just north of Meadow Mills along northwest side of Virginia Highway 624 and along Cedar Creek about 1 mi downstream of the Virginia Highway 622 bridge at Minebank Ford

Or **Rockdale Run Formation of the Beekmantown Group (Middle and Lower Ordovician)**--Interbedded limestone and dolostone. Limestone, bluish-gray, medium-gray, and dark-gray, fine- to medium-grained, thin- to medium-bedded, fossiliferous. Dolostone, medium-gray, fine- to-medium grained, medium-bedded, crystalline. Limestone beds also contain intraformational conglomerates, algal bioherms, bioclastic zones, and burrow mottling. Lithologies occur as carbonate cycles. Gray chert nodules common and occur as nodules up to 6 in. in diameter and as large masses up to several feet in diameter; large masses of Cryptozoon chert (Sando, 1957) litter soil in lower part of formation and form topographic knolls with little bedrock exposure. Gastropod *Lecanospira* is common in lower and middle parts of formation. Lower contact placed at base of first crystalline dolostone or dololaminite bed overlying dark-gray, thick-bedded limestone of Stonehenge Limestone (Os). Thickness approximately 1,500 ft. Unit best exposed in pastures at Epworth Chapel along Virginia Highway 625 and along Cedar Creek at the Virginia Highway 622 bridge at Minebank Ford

Os **Stonehenge Limestone of the Beekmantown Group (Lower Ordovician)**--Limestone, dark-gray, fine- to medium-grained, thick bedded, fossiliferous, with crinkly laminations and minor black chert. Also contains algal bioherms, intraformational conglomerates, bioclastic beds, and minor dolostone beds. Contact with underlying Conococheague Limestone (O€c) is gradational; base placed at first dark-gray limestone with crinkly siliceous laminations and above dolostone that caps Conococheague carbonate cycles. Thickness ranges from 600 to 650 ft. Best exposed along Cedar Creek, 0.5 mi upstream from Virginia Highway 622 bridge at Minebank Ford

O€c **Conococheague Limestone (Lower Ordovician and Upper Cambrian)**--Interbedded limestone, dolostone, dololaminite and sandstone. Limestone, medium-gray, fine-grained, thin- to medium-bedded. Dolostone and dololaminite, light-gray, fine-grained, medium-bedded. Sandstone, light-gray to buff, reddish-weathering, medium- to coarse-grained, calcareous. Limestone lithologies include intraformational conglomerates, algal bioherms, ribbon rock, and oolites. Lithologies occur as carbonate cycles. Lower 295 ft, Big Spring Station Member, consists of gray to buff, reddish-weathering, coarse-grained, calcareous sandstone; medium-gray, fine-grained limestone with intraformational conglomerate; and light-gray, fine-grained dolostone. Sandstone beds also occur in Big Spring Station Member in upper part of formation and form ridges. Base placed below first calcareous sandstone bed of Big Spring Station Member. Thickness ranges from 2,200 to 2,600 ft. Best exposed along Cedar Creek, downstream from Virginia Highway 628 bridge

€e **Elbrook Formation (Upper and Middle Cambrian)**--Interbedded limestone, dolostone, and shale. Limestone, medium-gray, fine- to medium-grained, thin- to medium-bedded. Dolostone, light- to medium-gray, yellowish-weathering, fine-grained, medium-bedded. Shale, gray, yellowish-weathering, dolomitic. Limestone contains algal bioherms, intraformational conglomerates, and dolomite mottling. Generally, lowest beds exposed are bluish-gray, medium- to thick-bedded limestone with dolomite mottles and medium-gray, thick-bedded dolostone. Middle part of formation contains cycles of bluish-gray limestone, light-gray dolostone, and argillaceous dolostone. Cycles of bluish-gray, algal limestone and grainstone and light-gray dolostone similar to the overlying Conococheague Limestone (Oec) occur in upper part of Elbrook. A distinctive lithology is yellowish weathering, thin-bedded dololaminite that appears shaly in weathered outcrops. Thickness is at least 2,300 ft. Formation is lowest unit exposed in quadrangle and occurs in the hanging wall of the North Mountain fault zone. Base of unit is faulted out along the North Mountain fault zone

€wb **Waynesboro Formation (Lower Cambrian)**--Maroon and yellow, shale and siltstone, and minor gray sandstone and dolostone. Does not crop out in quadrangle but occurs along North Mountain fault zone to southwest in Mountain Falls and Toms Brook quadrangles. Age of Waynesboro is Early Cambrian following Brezinski (1992) and Palmer (1971), who found Early Cambrian fossils in upper part of Waynesboro in Pennsylvania. Shown in cross section only

EXPLANATION OF MAP SYMBOLS

Contact--dashed where approximately located; dotted where concealed

Faults--dashed where approximately located; dotted where concealed

Thrust fault--Sawteeth on upper plate

Strike-slip fault--Arrows show direction of movement

Folds--Showing trace of axial surface and direction of plunge. Dashed where approximately located; dotted where concealed

Anticline

Syncline

Overturned syncline

Minor anticlne showing trend and plunge

PLANAR FEATURES

Strike and dip of beds

45 Inclined

Vertical

Horizontal

45 Overturned

45 **Strike and dip of cleavage**

OTHER FEATURES

Sinkhole

Travertine deposit

DISCUSSION

INTRODUCTION

The Middletown quadrangle is located in the Valley and Ridge province, largely in the Shenandoah Valley, in Frederick, Shenandoah, and Warren Counties, Virginia. Approximately 18,000 ft of Middle Cambrian to Upper Devonian sedimentary rocks are exposed and are overlain by Pleistocene(?) and Holocene surficial deposits. The map area is divided into three geologic regions: (1) shale, graywacke, and limestone of the Ordovician Martinsburg Formation of the Shenandoah Valley and Massanutten synclinorium, (2) Cambrian and Ordovician carbonates of the Shenandoah Valley southeast of the North Mountain fault zone, and (3) Ordovician through Devonian clastic rocks and minor limestone and dolostone northwest of the North Mountain fault zone (fig 1). Rocks of all three regions were folded and thrust faulted during the late Paleozoic Alleghanian orogeny. The terrain of the Shenandoah Valley generally is gently to moderately rolling with low relief. The area underlain by middle Paleozoic strata consists of a series of ridges and valleys with higher relief. Sinkholes and caves are fairly common in the carbonate rocks of the Shenandoah Valley.

Butts and Edmundson (1966) mapped the Frederick County portion of the quadrangle at a scale of 1:62,500. The adjacent Strasburg and Toms Brook quadrangles to the south and southwest, respectively, were mapped by Rader and Biggs (1976) at a scale of 1:24,000.

STRATIGRAPHY AND ENVIRONMENTS OF DEPOSITION

Rocks in the Middletown quadrangle range from Middle Cambrian to Late Devonian in age and consist of a variety of carbonate and clastic lithologies. Rocks from the Middle and Upper Cambrian Elbrook Formation through the Middle Ordovician Edinburg Formation are dominated by limestone and dolostone, whereas rocks from the Middle and Upper Ordovician Martinsburg Formation through the Upper Devonian Hampshire Formation are siltstone, sandstone, shale, and minor limestone. The environments of deposition of the rocks, the evolution of the sedimentary basins, and the tectonic history are interpreted from lithic and structural characteristics, facies changes (both lateral and vertical), and fossils.

The oldest stratigraphic units exposed are the Elbrook Formation (€e) and Conococheague Limestone (O€c). These units contain repetitive limestone and dolostone beds representing shallowing-upward subtidal, peritidal, and supratidal cycles in restricted shallow-marine environments. Cycles generally include, from the base upwards, intraformational conglomerate, grainstone, calcareous siltstone, algal bioherm, ribbon rock (interlaminated tan dolostone and gray limestone), and mudcracked dolostone. Dololaminite in the Elbrook and sandstone or dololaminite in the Conococheague cap these cycles. Orndorff (1988) indicated that the Cambrian-Ordovician boundary lies within the upper part of the Conococheague in northern Virginia on the basis of conodont biostratigraphy. Further studies in this area, and the possible redefinition of the Cambrian-Ordovician boundary (Derby, 1986), may move this systemic boundary higher in the Conococheague, possibly within approximately 10 to 20 ft of the contact with the overlying Stonehenge Limestone.

The Beekmantown Group is divided into a lower limestone unit, the Stonehenge Limestone (Os); a cyclic carbonate unit of limestone and dolostone, the Rockdale Run Formation (Or); and an upper dolostone unit, the Pinesburg Station Dolomite (Op). The peritidal cycles of the underlying Conococheague Limestone gradually grade upwards to the predominantly subtidal cycles of the Lower Ordovician Stonehenge Limestone accompanied by the loss of dolostone and sandstone in the Stonehenge. Channeled algal bioherms and siliceous laminated limestone is characteristic of the Stonehenge. Taylor and others (1992) suggested that the Stonehenge represents a third-order transgressive-regressive cycle in which the lowermost and uppermost thin-bedded units were deposited in a lagoon behind a barrier island, and the main algal body of the formation represents the transgression of an offshore barrier-island complex.

Overlying the Stonehenge, peritidal carbonate cycles reappear in the Lower and Middle Ordovician Rockdale Run Formation. These cycles indicate depositional environments similar to those of the Conococheague Limestone. The location of the Lower-Middle Ordovician boundary is in the upper part of the Rockdale Run in this area based on conodont studies (Harris and Harris, 1978; Harris and others, 1994).

Interbedded limestone and dolostone of the Rockdale Run Formation sharply give way upward in the section to predominantly dolostone of the Middle Ordovician Pinesburg Station Dolomite. The dolostone represents a restricted shallow-marine environment that was at times subaerially exposed as indicated by paleokarst features including irregular bedding and collapse breccia. Collapse breccia occurs in irregular beds as much as 5 ft thick with clasts as large as 1 ft in diameter.

Two periods of dolomitization are recognized. Some of the basal limestone of the Rockdale Run cycles contains dolostone clasts that were reworked from the dolostone that caps the top of the underlying cycle. These clasts suggest an early (penecontemporaneous) period of dolomitization (Walker and others, 1989). A late period of dolomitization is suggested by complete dolomitization of the limestone and dolostone cycles in the southwest corner of the map and in the adjacent Mountain Falls quadrangle (McDowell, 1995). In a pasture immediately north of Interstate Highway 81 (I-81) and west ofVirginia Highway 55, interbedded limestone and dolostone of the Rockdale Run Formation can be traced into a thick section of dolostone similar to the Pinesburg Station Dolomite. Conodonts from these rocks indicate that the limestone and dolostone beds are the same age as the section of dolostone along strike.

The New Market Limestone (On) generally unconformably overlies the Pinesburg Station Dolomite. Locally, the contact may be conformable where the lower 10 ft is a transition interval of interbedded dolomitic limestone and dololaminite. The New Market was deposited in a tidal flat or lagoon environment (Walker and others, 1989). Rocks immediately beneath the New Market were deposited on a Cambrian and Ordovician carbonate platform along the passive continental margin of North America. The New Market represents the change from passive margin to active margin deposition (Rader and Read, 1989) in response to the Taconian orogeny. The remainder of the Middle Ordovician section, from the Lincolnshire Limestone to the Martinsburg Formation, represents the transition from continental shelf to ramp to foreland-basin deposition. The Lincolnshire Limestone (Ol) represents the beginning of the deepening of the Middle Ordovician basin in the central Appalachians. The unit represents a more open marine environment than the New Market, possibly an inner ramp deposit (Walker and others, 1989). Much of the Edinburg Formation (Oe) was deposited in a continental slope environment, probably on a deeper ramp than the Lincolnshire Limestone (Walker and others, 1989). Several metabentonite beds in the Edinburg Formation and overlying Stickley Run Member of the Martinsburg Formation indicate Middle Ordovician volcanism (Walker and others, 1989).

Further deepening of the foreland basin during deposition of the Martinsburg Formation (Om) resulted in an increase in clastic sediments, a gradual loss of carbonate rocks, and the formation of turbidite sequences. The Stickley Run Member (Epstein and others, 1995) (Oms) of the Martinsburg Formation represents the end of Cambrian and Ordovician carbonate deposition. Clastic sediments of the remainder of the Martinsburg were derived from an island-arc system to the east that filled the basin with shale, siltstone, and graywacke (Walker and others, 1989).

The foreland basin became shallower, as indicated by the deposition of the Oswego Sandstone (Oo) which was deposited in progressively shallower nearshore environments including offshore barrier bar, lagoon, and tidal channel (Patchen, 1978). The source of sediments into the basin was from continued uplift to the east that occurred as the Ordovician sea regressed northward (Robinson, 1987).

Additional clastic sediments were deposited in river channels, floodplains, and deltaic environments of the Juniata Formation (Oj; shown in cross section only) and in submerged delta-estuarine and beach deposits of the Tuscarora Quartzite (St) (Folk, 1960). Open-marine to brackish shallow-water deposits of the Rose Hill Formation formed in an oxidizing environment (Folk, 1960; Smosna and Patchen, 1991). The Keefer Sandstone was probably deposited in a lagoon, barrier-island beach, or mainland beach environment (Folk, 1960). Further foreland basin deposition in the Silurian occurred in subtidal marine (McKenzie Formation), shallow subtidal marine and coastal mudflat (Bloomsburg Formation), marginal tidal mudflat (Wills Creek Formation), and intertidal and supratidal (Tonoloway Limestone) environments (Smosna and Patchen, 1991; Cotter, 1993).

A change from predominantly clastic deposition to predominantly carbonate deposition occurred in the Late Silurian. Limestone of the Upper Silurian and Lower Devonian Helderberg Group (which, in this region, includes the Keyser, New Creek, and Licking Creek Limestones) was deposited during a period of tectonic quiescence on a gently sloping carbonate ramp on the eastern side of the basin. Subtidal to supratidal deposition (Head, 1969; Smosna, 1988) occurred across the Silurian-Devonian boundary in the uppermost part of the Keyser Limestone (Denkler and Harris, 1988). The New Creek and Licking Creek Limestones represent middle rise and lower rise depositional environments (Smosna, 1988).

Another episode of clastic sedimentation began with deposition of the Oriskany Sandstone in shallow-marine, offshore barrier bar complexes (Welsh, 1984). Deposition of the Oriskany was followed by deposition of the Needmore Shale, Marcellus Shale, Mahantango Formation, and Brallier Formation in deeper water of the foreland basin, which in turn was followed by deposition of the Chemung and Hampshire Formations in shallow water (Woodrow and others, 1988). The Chemung and Hampshire sediments gradually filled the basin as recognized by progressively shallower environments of deposition.

SURFICIAL GEOLOGY

Surficial deposits in the Middletown quadrangle consist of terrace deposits, colluvium, alluvium, and travertine. The terrace deposits (Qt) adjacent to Cedar Creek consist of mostly rounded cobbles of sandstone in a deeply weathered silt matrix. The cobbles were derived from Silurian and Devonian rocks northwest of the North Mountain fault zone and were deposited at altitudes between 800 ft near the North Mountain fault zone and 600 ft in the southern part of the quadrangle. These terrace deposits are generally 150 ft above creek level. Thickness of the terrace deposits ranges from 20 to 50 ft. Thin deposits of rounded sandstone cobbles occur sporadically throughout the quadrangle as much as 200 ft above Cedar Creek. Abundant cobbles up to 7 in. long in a medium-brown loamy soil are scattered in a field southwest of Virginia Highway 638, 1.15 mi east-southeast of Marlboro. This deposit is 1.35 mi from Cedar Creek at its nearest point, and is separated from the creek by the 100-ft-high Poplar Ridge held up by sandstone of the upper part of the Conococheague Limestone. Where the ridge is absent, Cedar Creek is 2.5 mi away from the cobbles. The cobbles may be remnants of terrace deposits that were more aerially extensive and may indicate that large streams in the Shenandoah Valley meandered over great distances.

Colluvium is found on the slopes of Little North Mountain. These deposits consist of poorly sorted, angular and subangular cobbles and boulders of sandstone and quartzite derived from Silurian units that hold up the ridge. The colluvium formed by mass wasting probably during the Pleistocene and Holocene and is concentrated in hollows that, in general, are too small to depict on the map.

Alluvium (Qal) consisting of clay, silt, and lesser sand with angular to subrounded gravel, cobbles, and some boulders, underlies flood plains along creeks. In the area northwest of the North Mountain fault zone and along the entire length of Cedar Creek, alluvium contains abundant rock clasts whereas small creeks in the carbonate rocks of the Shenandoah Valley southeast of the North Mountain fault zone have generally fine grained alluvium with minor rock clasts. In the Martinsburg Formation outcrop belt, alluvium consists of well to crudely bedded clayey silt with weathered shale fragments.

Travertine occurs at two localities along Cedar Creek. The first is about 300 ft upstream from the Virginia Highway 628 bridge over Cedar Creek near Marlboro, .5 mi downstream from a spring at Marlboro where Fawcett Run drops approximately 15 ft at a waterfall into Cedar Creek. The second is located about 1.5 mi downstream from the bridge. Travertine is deposited where spring-fed stream waters supersaturated with calcium carbonate flow over rough stream beds. A combination of increased temperature and aeration due to the turbulence causes the loss of carbon dioxide and deposition of calcite (White, 1988).

SINKHOLES

Sinkholes are closed depressions that result from subsidence due to solution of the bedrock and collapse of subsurface solution cavities. They are found throughout the area and are underlain by Cambrian and Ordovician carbonate rocks. Orndorff and Goggin (1994) determined that rocks in the interval from the Rockdale Run Formation through the Edinburg Formation had the highest concentrations of sinkholes in the Winchester area. Intrenched streams also control sinkhole development. In the Shenandoah Valley, sinkholes tend to be more abundant and somewhat larger near intrenched streams. The greater development of sinkholes near streams can be attributed to the steepened hydraulic gradient and increased rate of ground-water flow in these areas (Hubbard, 1983; White, 1988). Sinkholes are found in rocks in the interval from the Elbrook Formation through the Lincolnshire Limestone along Cedar Creek. However, no large sinkholes occur more than 2,000 ft from Cedar Creek in the Elbrook Formation, Conococheague Limestone and Stonehenge Limestone. Sinkholes in rocks in the interval from the Rockdale Run Formation through Edinburg Formation occur throughout the quadrangle. Several caves occur in areas where there is a high density of sinkholes.

STRUCTURAL GEOLOGY

Rocks of the Middletown quadrangle are divided into three lithotectonic units. From southeast to northwest, these are the tightly folded and cleaved rocks of the Martinsburg Formation (lithotectonic unit A, fig. 1), the generally southwest-plunging folded and thrust-faulted rocks of the Cambrian and Ordovician carbonate valley southeast of the North Mountain fault zone (lithotectonic unit B, fig. 1), and the northwest-verging upright and overturned folded rocks of the Valley and Ridge province northwest of the North Mountain fault zone (lithotectonic unit C, fig. 1). In the transition area between the Martinsburg Formation and the Cambrian and Ordovician carbonate valley, folds have wavelengths intermediate between those of lithotectonic units A and B. The boundary between the Cambrian and Ordovician carbonate valley and the Valley and Ridge is the complex North Mountain fault zone.

The rocks in the hanging wall southeast of the North Mountain fault zone are on the northwest limb of the Massanutten synclinorium, a regional fold that extends from central Pennsylvania to just south of Staunton, Va. The folds and faults in the Middletown quadrangle resulted from the Late Mississippian and Permian Alleghanian orogeny (Hatcher and others, 1989).

Folds

Folds range from northeast-trending, tight chevron and curvilinear folds in the Martinsburg Formation; to upright, northwest-verging folds in the Cambrian and Ordovician carbonate rocks; to upright and overturned folds in the mostly clastic Silurian and Devonian rocks of the Valley and Ridge. Bedding in the Cambrian and Ordovician carbonate valley and Martinsburg Formation show a general southeast dip consistent with the west limb of the Massanutten synclinorium (figs. 2A and 2B). However, the highly folded Martinsburg Formation shows some northwest-dipping beds (fig. 2B). The regional orientation of folds is about N. 35° E. as estimated from poles to bedding. Folds of both lithotectonic units A and B plunge gently to the southwest at about 6°, S. 33° W. (estimated from poles to bedding and intersection of bedding and cleavage, figs. 2A, 2B, and 2F) as part of the southwestward-plunging Massanutten synclinorium in this region (fig. 1).

Examples of these southwest- plunging folds in the carbonate valley include the Belle Grove anticline, Marsh Brook syncline, Ridings Hill anticline, and Buffalo Marsh Run syncline (fig. 1). The Marsh Brook syncline generally plunges southwest, but in places plunges northeast for very short distances. Epstein (1993) noted a more northerly trend, N. 10°-15° E., in some folds in the Martinsburg Formation which probably represent changes in the orientation of incremental strain during different stages of deformation. A disharmony in fold wavelengths occurs between the Martinsburg Formation and the Cambrian and Ordovician carbonate rocks; the latter have folds with longer wavelengths (see cross sections B-B' and D-D'). Middle Ordovician limestone units have folds with intermediate wavelengths between the two extremes. This disharmonic folding may be due to rheological differences of the rock units.

Only one major fold occurs in the Silurian and Devonian rocks of the Valley and Ridge province northwest of the North Mountain fault zone. The Mount Pleasant syncline is overturned, verges northwest, and plunges gently to the northeast at about 10°, as estimated by poles to bedding (figs. 2C and 2D). Poles to bedding are spread in the Silurian and Devonian rocks due to an orocline. The orocline is also evident in the Cambrian carbonate rocks near the North Mountain fault zone.

Poles to cleavage indicate that the axial-planar cleavage fans around folds (fig. 2E) and is best developed in rocks of the Martinsburg Formation.

Faults

The North Mountain fault zone extends from central Virginia to south-central Pennsylvania, and is made up of many fault slices of older rock units over younger rock units. The footwall encompasses Silurian and Devonian rocks of the overturned southeast limb of the Mount Pleasant syncline. The hanging wall encompasses Cambrian carbonate rocks of the west limb of the Massanutten synclinorium. The North Mountain fault zone in the Middletown quadrangle is as much as 2,500 ft wide and contains fault slices of various Ordovician and Silurian rocks (see cross sections A-A', B-B', and C-C'). Rocks within the North Mountain fault zone on the southeast side are generally upright, whereas rocks within the fault zone on the northwest side are generally overturned. The change in orientation occurs within the highly deformed Martinsburg Formation. The change from upright to overturned rocks suggests that the North Mountain fault zone developed from as a fault-propogation fold. Lower and Middle Ordovician carbonate rocks were derived from the upright limb of an anticline on the southeast side of the fault zone; Upper Ordovician and Silurian rocks were derived from the overturned limb of an adjacent syncline. Along Virginia Highway 714, 1.25 mi northeast of Virginia Highway 55, five fault slices contain progressively younger rocks toward the northwest (see cross section C-C').

Three thrust faults in the Cambrian and Ordovician carbonate rocks are associated with synclines. Thrust faults on both limbs of the Marsh Brook syncline break up the limbs of that syncline (see cross section D-D').

Joints

Joints within the Martinsburg Formation and the Cambrian and Ordovician carbonate valley vary with rock type. The Cambrian and Ordovician carbonate rocks are brittle compared to the ductile Martinsburg Formation which contains a well-developed slaty cleavage. The carbonate rocks exhibit two sets of cross-strike joints that trend approximately N.80°W. and N. 15° W., and one set of longitudinal joints at about N. 15° E. (fig. 2G), while rocks of the Martinsburg Formation contain two sets of cross-strike joints at about N. 35°W. and N. 25° W. (fig. 2H). The spread of data suggests that some joint sets may be local features.

ECONOMIC GEOLOGY

The only unit of economic interest is the high-calcium New Market Limestone. Two active quarries operate in the Middletown quadrangle, but many abandoned quarries exist along the outcrop belt of the New Market. One such abandoned quarry is now used as a recreational area.

Excluding the lowermost beds of the New Market Limestone, which contain some magnesian limestone, the unit is as much as 98 percent calcium carbonate (Edmundson, 1945) and is used in the manufacture of steel, aluminum, glass, and paper as well as for a waste stream neutralizer and agricultural lime. In the map area, the New Market ranges from 144 to 203 ft thick and generally crops out in a thin sinuous belt from the southwest corner of the quadrangle to the east side, and as slivers along the North Mountain fault zone. Within the Marsh Brook syncline, the outcrop belt of the New Market is wider due to faulting and folding.

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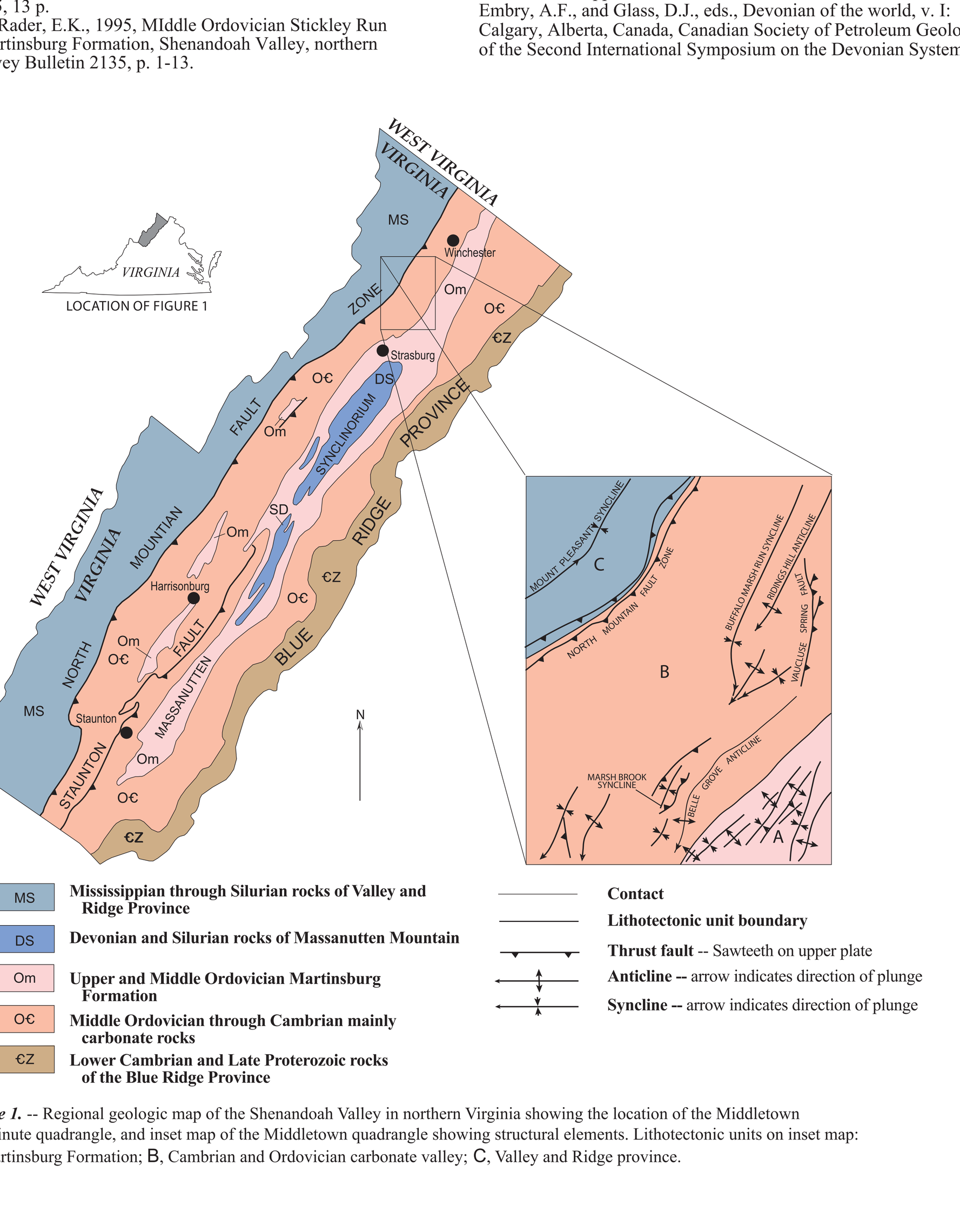

Figure 1. -- Regional geologic map of the Shenandoah Valley in northern Virginia showing the location of the Middletown 7.5-minute quadrangle, and inset map of the Middletown quadrangle showing structural elements. Lithotectonic units on inset map: A, Martinsburg Formation; B, Cambrian and Ordovician carbonate valley; C, Valley and Ridge province.

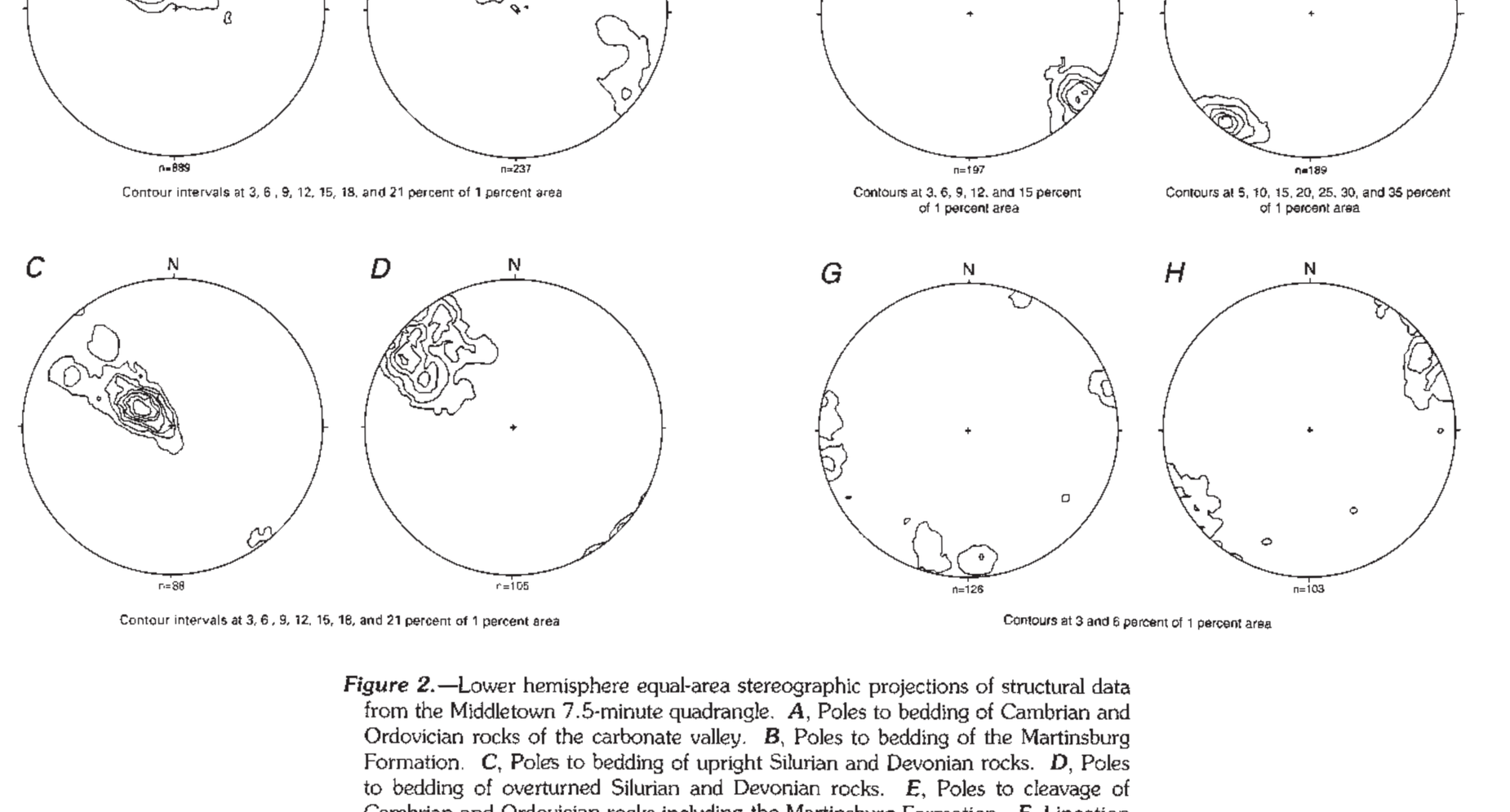

Figure 2.—Lower hemisphere equal-area stereographic projections of structural data from the Middletown 7.5-minute quadrangle. ***A***, Poles to bedding of Cambrian and Ordovician rocks of the carbonate valley. ***B***, Poles to bedding of the Martinsburg Formation. ***C***, Poles to bedding of upright Silurian and Devonian rocks. ***D***, Poles to bedding of overturned Silurian and Devonian rocks. ***E***, Poles to cleavage of Cambrian and Ordovician rocks including the Martinsburg Formation. ***F***, Lineation of intersection of bedding and cleavage of Cambrian and Ordovician rocks including the Martinsburg Formation. ***G***, Poles to joints in Cambrian and Ordovician rocks of the carbonate valley. ***H***, Poles to joints in the Martinsburg Formation. n, number of measurements.

GEOLOGIC MAP OF THE MIDDLETOWN QUADRANGLE, FREDERICK, SHENANDOAH, AND WARREN COUNTIES, VIRGINIA

By

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1999